Amperion PLT Measurements in Crieff

Publication date: 11 May 2005

Contents

Summary

This project was designed to update Ofcom on the nature and extent of the unavoidable radio frequency leakage emissions that radiate from modern Power Line Telecommunications networks. Particular interests were the rate at which PLT leakage emission levels decay with distance from their source and the effectiveness of any mitigation measures that can be applied by PLT equipment manufacturers and operators to reduce any adverse impact these leakage emissions may have on radio reception.

This report covers the third and last part of the project. It is specific to the situation at Crieff where Scottish and Southern Energy plc were trialling the use of Amperion PLT equipment on a 2.3 km section of their 11 kV overhead power line, just outside the town. This PLT trial is believed to be the first in the UK to utilise the 11kV overhead power network as a broadband transmission line and also the first to use PLT frequency spectrum above, as well as below, 30MHz.

Amperion equipment is designed for PLT access networks in the USA where it must comply with leakage emission limits published in the FCC part 15 regulations. For this report, radiated leakage emission levels were measured using methods recently specified by the FCC, for overhead PLT networks. Leakage emission levels from the Amperion equipped 11kV overhead line were found to be up to 8dB in excess of the FCC Part 15 emission limits for frequencies below 30 MHz and up to 27dB in excess of the FCC Part 15 emission limits at frequencies above 30 MHz.

By normalising launch power and measurement distances, radiated leakage emission levels from the overhead Amperion PLT network, at frequencies below 30 MHz, were found to be 20dB in excess of the leakage emission levels from two, largely underground, PLT access networks recently measured during this project.

For frequencies below 30MHz, both magnetic and electric field measurements were taken at distances from 10 to 300 metres from the overhead line. These measurements were used to assess the regression characteristic of the PLT network. The magnetic field regression results, at approximately 27dB/decade of distance, were found to be comparable with those obtained recently from a, largely underground, PLT access network. For PLT frequencies above 30MHz the electric field was measured at distances from 10 to 3000 metres from the overhead line. Regression over this path was affected by ground reflections and varied between 10 and 21dB/decade.

To provide an interference mitigating measure, Amperion PLT equipment has a downstream notching facility. This was tested at 10 metres from the overhead line by implementing a 20dB notch to cover the 21 MHz broadcast band. The notch proved to be effective by ‘uncovering’ several AM broadcast transmissions that were delivering field strengths in excess of the minimum protected value of 40dBμV/m and would otherwise have been buried under the PLT leakage emissions.

Given the relaxed nature of the FCC part 15 emission limits, a 20dB notch is not an effective interference mitigation measure for weak signal reception that is limited only by the local spectrum noise floor. For example, with the 20dB notch implemented, PLT leakage emissions, previously at the FCC part 15 10 metre limits, would be

approximately 40 dB above the naturally occurring spectrum noise floor, of -10dBμV/m, at 10 metres from the overhead line and 20dB above the noise floor at 100 metres from the line. Accordingly, FCC part 15 compliant leakage emissions from a notched PLT line would contribute noise to the HF spectrum at distances as far as 1km from the line.

Section 1

Background

Power Line Telecommunications (PLT), Power Line Communications (PLC) and Broadband *over* Power Line (BPL) are all terms used to refer to the process of delivering high frequency broadband data over existing electricity supply cables, on a secondary use basis. The generic term PLT will be used in this report.

PLT products are designed to provide broadband internet access using the electricity distribution network as a transmission medium. In concept, PLT has some similarities with DSL in that it delivers high frequency broadband data using existing infrastructure cables on a secondary use basis.

In the UK, access PLT networks feature high frequency internet signals passed between an electricity sub-station and the PLT customers connected to it. A typical 500 kVA substation can serve up to about 200 electricity users, situated within a 200 metre radius, with the potential PLT customer base being a small percentage of these. To serve these customers with broadband internet access, each PLT enabled electricity sub-station must be connected to an ISP via a dedicated high capacity link.

In the USA some access PLT networks are configured differently. This is because, outside towns, the electricity distribution network is largely based on medium voltage overhead lines with small capacity pole mounted transformers each supplying a few customers. This has led to the development of PLT equipment that operates over the MV network.

Electricity supply cables are not designed, screened or balanced for high frequency use and even when buried below ground they can radiate significant leakage emissions. PLT leakage emissions occupy parts of the high frequency radio spectrum above 2 MHz and have the potential to interfere with the reception of radio communication services including short wave broadcasts.

The PLT interference issue has proved to be contentious and remains under discussion both within Europe and elsewhere. Various radiated emission limits have been proposed, either for establishing network compliance or less rigidly, for the purposes of adjudication in cases of reported interference. It appears, however, that none of the proposed emission limits can currently satisfy the dual objective of protecting radio reception whilst, at the same time, allowing PLT to operate in a commercially viable manner.

Section 2

Introduction

Scottish and Southern Energy's PLT Trials

Scottish and Southern Energy plc, a major UK power utility, is currently conducting several trials of access PLT products. Small scale trials are in place at Crieff and Campbeltown in Scotland with larger trials underway at Stonehaven in Scotland and at Winchester in England.

S&SE's promotional material for their PLT based broadband products can be found at:

http://www.hydro.co.uk/broadband/index.asp

http://www.southern-electric.co.uk/broadband/

Some of these trials are receiving external support, including that from central government through the DTI broadband fund. More details can be found at:

http://www.ssetelecom.co.uk/news/index.asp

http://www.scottish-enterprise.com/sedotcom_home/services-to-business/broadband/broadband-news/power_line_trial.htm

Crieff 11kV overhead line PLT trials

In addition to their trials of access PLT products within the town, S&SE have recently installed PLT equipment on a 2.5 km section of their 11 kV medium voltage overhead distribution network just outside Crieff. This section of overhead distributor has been configured so that it can operate as part of the backhaul for the Crieff access PLT networks.

This PLT network trial, believed to be the first of its type in the UK, uses equipment supplied by the American company, Amperion.

Amperion equipment is built around the Spanish DS2 PLT chipset that employs OFDM signal architecture.

Measurement Objectives

This project was designed to update Ofcom on the nature and extent of the unavoidable radio frequency leakage emissions that radiate from modern Power Line Telecommunications networks.

Particular interests were the rate at which PLT leakage emission levels decay with distance from their source and the effectiveness of any mitigation measures that can be applied by PLT manufacturers and operators to reduce any adverse impact of these leakage emissions on radio reception.

The specific objectives of this work were:

1.) To measure the level of radio frequency leakage emissions in the immediate vicinity of S&SE's Amperion enabled 11kV overhead PLT network using methods similar to those originally proposed in FCC 04-29 **(Ref. 1)** and confirmed in FCC 04-245 **(Ref. 2)**

This information is required to establish the absolute leakage emission levels from the 11 kV OH network to compare these levels with the limits contained in FCC Part 15. **(Ref. 3)**

2.) At frequencies below 30 MHz, to measure both the magnetic and electric field in the immediate vicinity of S&SE's Amperion enabled 11kV overhead PLT network and establish the correlation between the two measurements.

The information is required both to understand the nature of the 11kV overhead line as a radiator and to discover whether it is necessary or advantageous to make electric field measurements below 30 MHz where traditionally only magnetic field measurements are normally made.

3.) To assess the rate at which both the magnetic and electric field leakage emissions from the 11kV overhead line regress as the measurement distance is increased from 10 to 30 metres.

This information is required to assess the validity of the distance conversion factor contained in FCC Part 15 measurement procedures that are intended to allow 10 metre measurements to be compared with the FCC Part 15, 30 metre limit.

4.) To measure both magnetic and electric field leakage emissions at defined distances away from the 11kV overhead network until the emission levels fall to the noise floor of the measuring system

This information is required to establish the regression characteristic of the 11 kV overhead PLT network.

5.) To characterise the Amperion PLT spectrum and measure the depth of the notches that can be applied.

This information is required to facilitate the assessment of the interference potential of the network and also the mitigation measures that can be applied to alleviate such problems.

Section 3

Summary of findings

These findings relate only to the S&SE 2.3 km section of 11 kV overhead power line near Crieff fitted with Amperion Griffin PLT equipment and specifically to the condition in which it was offered for testing. Where operating parameters are stated they were provided by the manufacturers and are reproduced here in good faith. They were not, however, verified by the measurement team.

Leakage Emissions at 10 metres from the 11 kV Overhead Power Line

The Amperion Griffin equipment, operating with a stated launch PSD of -50dBm/Hz, produced a maximum field strength level of 60dBuV/m below 30MHz and 59dBuV/m above 30MHz. These levels exceed the FCC Part 15 compliance limits by up to 8 dB below 30MHz and 27dB above 30MHz.

Comparison of E and H fields at 10 metres from the Overhead Power Line

In the downstream PLT spectrum block, centred on 21.8MHz, the maximum difference between the Electric and Magnetic Field strength was 8 dB in favour of the magnetic field. This magnetic field maximum occurred at a distance of half a wavelength along the line from the launch point.

Field Strength Regression away from the Overhead Line

Below 30MHz the magnetic field regression, measured at 10, 30, 100 and 300 metres from the overhead line, was approximately 27dB/decade and the electric field regression, over the same path, varied between approximately 16 and 21dB/decade. Above 30MHz the electric field regression, measured at 10; 30; 100; 300; 1000 and 3000 metres from the overhead line, varied between 10 and 20 dB/decade.

The effectiveness of Notching

A sharp sided 20 dB notch, covering the 13 metre broadcast band from 21.45 to 21.9 MHz, was inserted into the Span 1 downstream PLT spectrum.

With the downstream launch power set to its maximum value of -50dBm/Hz, the 10 metre field strength of the unnotched spectrum, measured at ¾ λ along from the launch point, was 55dBμV/m. This is approximately 3dB above the FCC part 15 limits. Under those conditions, several broadcast stations within the 20 dB notch that were delivering field strengths in excess of the minimum protected value of 40dBμV/m, were clearly audible on the measuring receiver.

Given the relaxed nature of the FCC part 15 emission limits, a 20dB notch is not an effective interference mitigation measure for weak signal reception that is limited only by the local spectrum noise floor. For example, with the 20dB notch implemented, PLT leakage missions, previously at the FCC part 15 10 metre limits, would be approximately 40 dB above the naturally occurring spectrum noise floor, of -10dBμV/m, at 10 metres from the overhead line and 20dB above the noise floor at 100 metres from the line. It follows that FCC part 15 compliant leakage emissions from a notched PLT line would contribute noise to the HF spectrum at distances as far as 1km from the line.

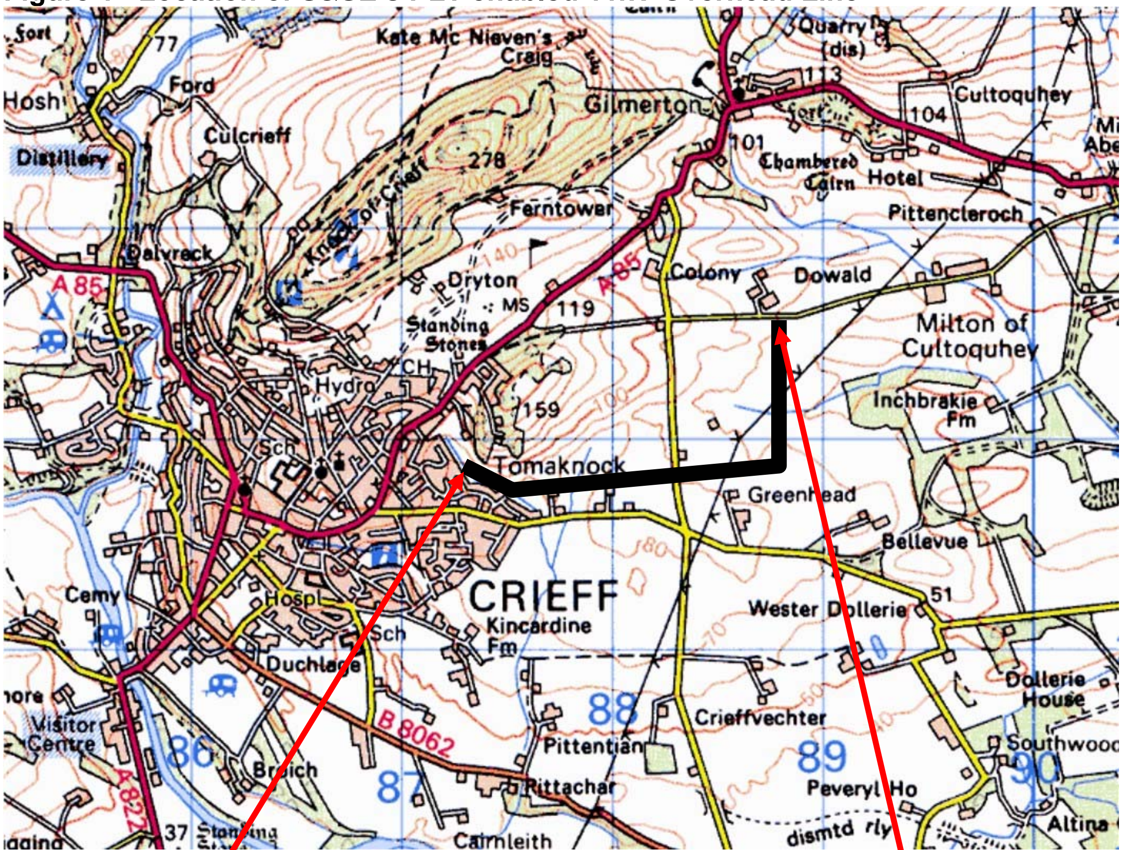
Section 4

Test Notes

Measurement Location

The Crieff overhead PLT network comprises a 2.3 km stretch of 11 kV line running across farm land.

Figure 1 Location of S&SE's PLT enabled 11kV Overhead Line



Scale: 1km Squares

Upstream launch point **Downstream launch point**

The thick black line shows the approximate route of the PLT enabled part of S&SE's 11kV overhead network. This has been configured to function as part of S&SE's backhaul for their access PLT deployments within the town.

At the downstream launch point, downstream data is supplied to an Amperion Griffin injector unit by Wi-Fi link from a nearby equipment cabinet. The cabinet has a fibre connection from the 132kV overhead line that can be seen on the map crossing the road diagonally to the east of the downstream launch point.

At the upstream launch point, downstream data from an Amperion Griffin unit is transmitted by Wi-Fi link to an Amperion Lynx unit in a nearby electricity substation. Using the Amperion Lynx PLT equipment, the downstream data travels on by underground 11kV cables to S&SE's 'point of presence' in the town.

The upstream data uses the reverse of this process.

The Amperion PLT System

The Crieff overhead PLT network deployed by S&SE uses Amperion Griffin PLT equipment manufactured in the USA. Details of the company and its products can be found at: http://www.amperion.com/

Amperion Griffin PLT equipment employs OFDM signal architecture and is built around the DS2 chipset. More information can be found at: http://www.ds2.es

The OFDM signal comprises 1280 carriers with 1.1 kHz spacing. The downstream spectrum has 768 carriers and occupies a 3.75 MHz bandwidth. The upstream spectrum comprises 512 carriers with a 2.75 MHz bandwidth.

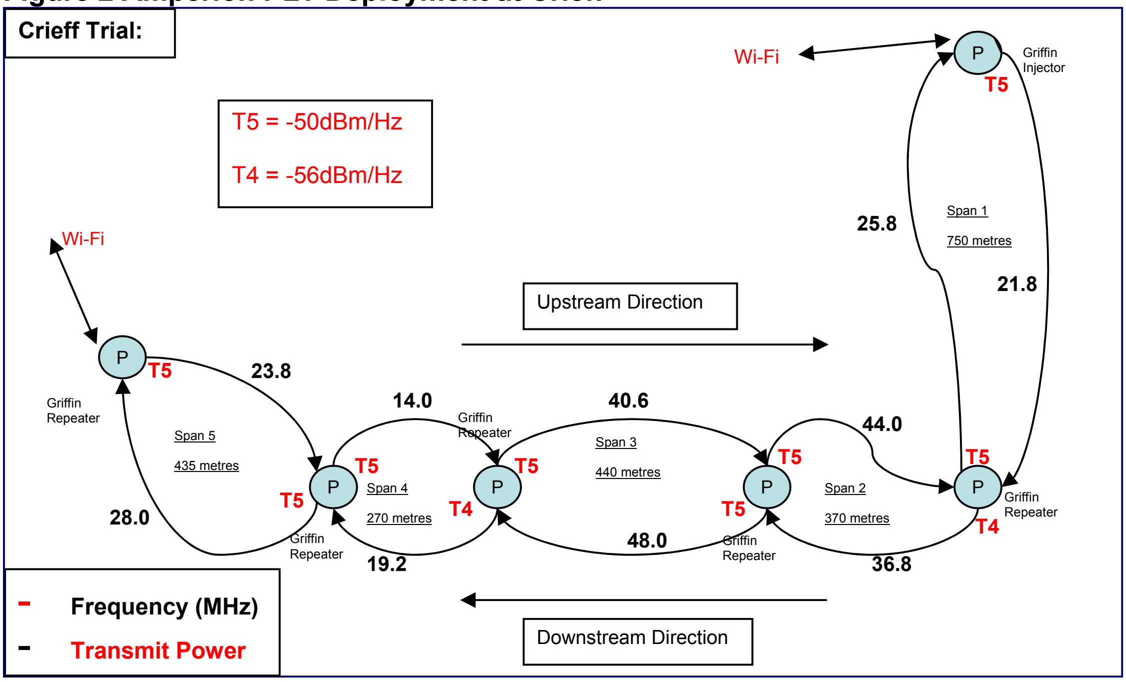
Amperion Network Architecture

The total Crieff deployment comprises 6 Griffin units; one at each end of the 2.3 km line and 4 repeaters. This requires five duplex frequency spans which were arranged as shown below.

Table 1

Span	Length	Downstream Spectrum	Upstream Spectrum
1	750m	21.8 MHz ± 1.875 MHz	25.8 MHz ± 1.375 MHz
2	370m	36.8 MHz ± 1.875 MHz	44.0 MHz ± 1.375 MHz
3	440m	48.0 MHz ± 1.875 MHz	40.6 MHz ± 1.375 MHz
4	270m	19.2 MHz ± 1.875 MHz	14.0 MHz ± 1.375 MHz
5	435m	28.0 MHz ± 1.875 MHz	23.8 MHz ± 1.375 MHz

Figure 2 Amperion PLT Deployment at Crieff



The downstream spectrum is continuous. The upstream spectrum varies according to traffic requirements but maintains a 20% duty cycle under quiescent conditions.

Test Equipment

Radiated leakage emission measurements were made using Rohde & Schwarz ESCS30 EMI measuring receivers, meeting CISPR 16 requirements, and one of four broadband calibrated antennas.

1.) Rohde & Schwarz HFH2-Z2, CISPR 60cm active loop.

2.) Rohde & Schwarz HM525, low noise, active loop.

3.) Schwarzbeck EFS 9219 short active dipole.

4.) Schaffner Chase VBA6106 passive bi-conical dipole.

The active antennas and the measuring receiver were powered by separate integral or co-located batteries both to facilitate portability and to eliminate the possibility of ground loop currents adversely affecting the measurements.

With the 9 kHz bandwidth and peak detector settings used, the magnetic field measuring system, based on the Rohde & Schwarz HM525 low noise loop antenna had a noise floor of approximately 10dBμV/m. This is 17 to 20 dB lower than can be achieved with the standard Rohde & Schwarz HFH2-Z2 60cm loop antenna. This low noise floor was necessary to measure the PLT leakage emissions at distances between 30 and 300 metres from the network.

Had the standard Rohde & Schwarz HFH2-Z2 60 cm loop antenna been used, most PLT leakage emissions would have been below the measuring system noise floor at distances much beyond about 30 metres from their source.

S&SE support during the measurements

Engineering representatives from S&SE were present throughout the test period to liaise with Amperion, implement safety procedures and witness the measurement processes.

PLT Network power settings

The launch power of the Amperion PLT equipment has a control range of 24dB that is adjustable by the network operator in 6 dB steps. In accordance with normal practise and FCC Part 15 measurement requirements, the launch power was set to its maximum value of -50dBm/Hz during the measurements.

Presentation of the results

The measuring receiver was set to scan across the PLT carrier frequencies in 5 kHz increments for frequencies below 30 MHz and in 60 kHz increments for frequencies above 30MHz. A measurement was recorded automatically at each increment.

The large quantity of data collected was read into a spreadsheet programme for subsequent analysis and production of the charts presented in this report.

Section 5

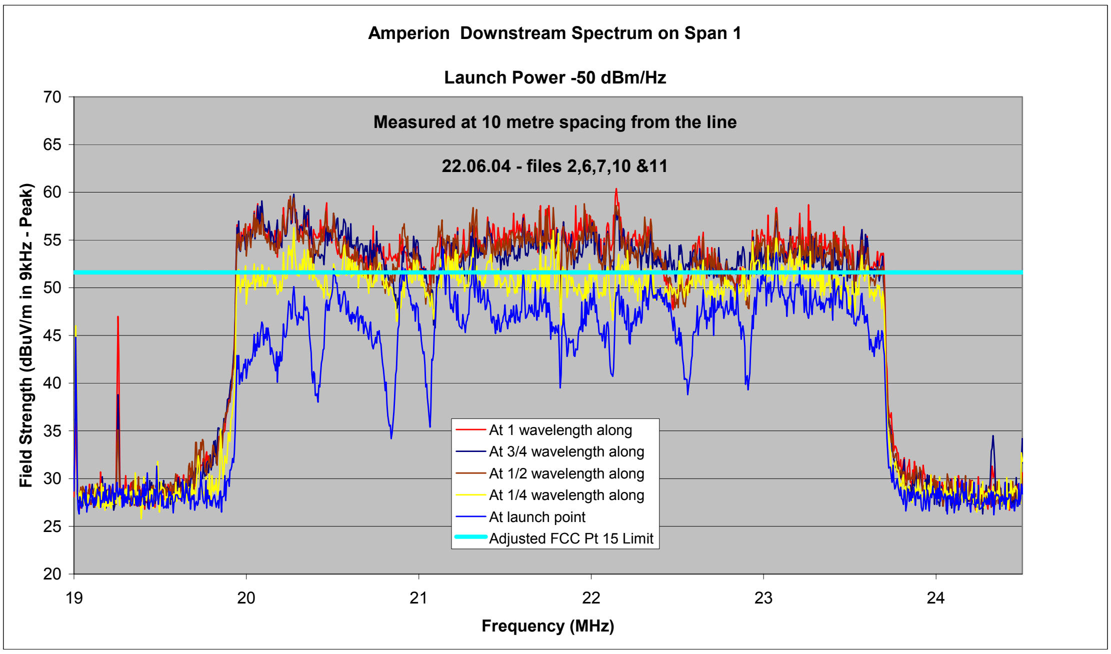
Measurement Results

10 metre radiated emission levels for frequencies below 30 MHz (Span 1)

There are currently no radiated emission limits applicable to PLT use within the UK so for reference purposes the American FCC Part 15 limit, applicable to PLT networks in the USA, has been shown in this report.

The FCC Part 15.209 radiated emission limit, between 1.705 and 30MHz, is 30uV/m (29.5dBuV/m) measured at 30 metres from the source in a 9 kHz bandwidth using a Quasi-Peak detector. To match this to the measuring conditions used during this work, the limit was adjusted for 10 metres by adding the FCC Part 15.31 40 dB/decade distance correction factor of 19 dB (40 log 30/10) and for the use of a peak detector by adding 3dB to account for the measuring receiver's response to the OFDM signal. (+22dB in total)

Figure 3 Leakage Emission Levels compared with FCC Part 15 Limits



The measurements shown above were made having regard to the proposed measurement guidelines for overhead PLT networks contained in Appendix C of FCC document 04-29 dated February 2004 **(Ref 1)**

Magnetic field measurements were made with a Rohde & Schwarz HFH2-Z2 60cm loop antenna and converted into electric field units by adding 51.5 dB.

Measurements were made at ¼ wavelength intervals along the line from the injection point but were limited to one wavelength (at 21.8 MHz) due to the farmland terrain beyond that distance being inaccessible by the normal road vehicles available to Ofcom.

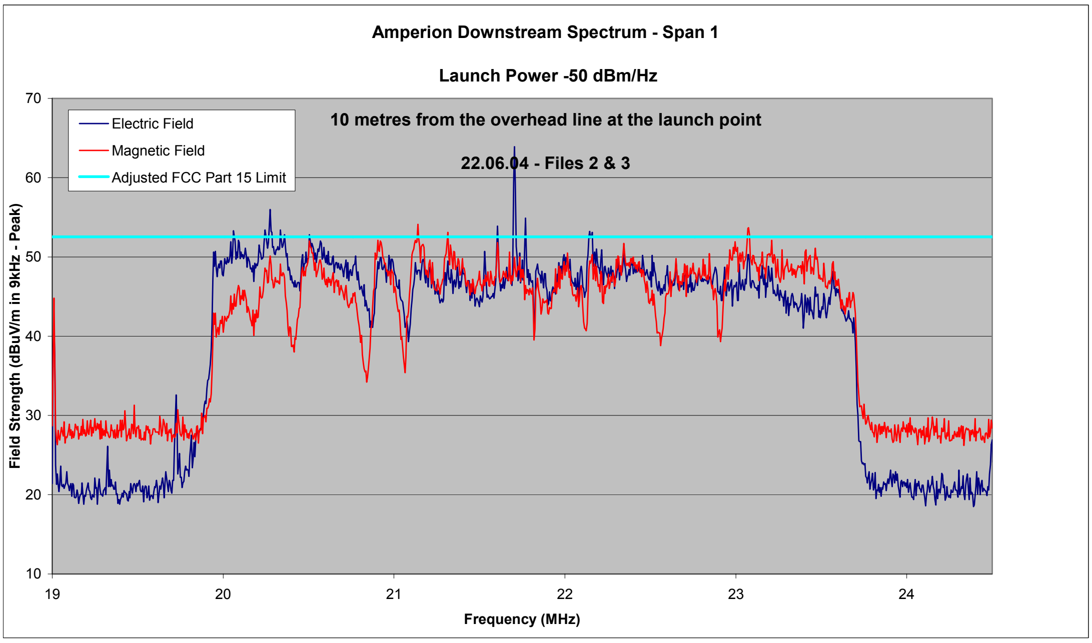
It can be seen that 10 metre emissions peaked at 60dBµV/m, some 8dB above the FCC part 15 limits and that power levels would need to be set to their -62dBm/Hz setting to ensure compliance at these measurement positions.

Comparison of E and H fields at 10 metres – below 30MHz (Span 1)

Figure 4 Measuring Equipment by the Downstream injection Point

The charts in this section show both the vertically polarised electric field, measured with the short active dipole antenna and the equivalent electric field, measured with the loop antenna.

Figure 5 Leakage Emissions at the injection point – 10 metre measurement



Following the convention for magnetic field measurements below 30 MHz the magnetic field has been expressed in electric field units assuming a plane wave conversion factor of 51.5 dB (20 log 377Ω)

Figure 6 Emissions at 1/4 λ from the injection point – 10 metre measurement

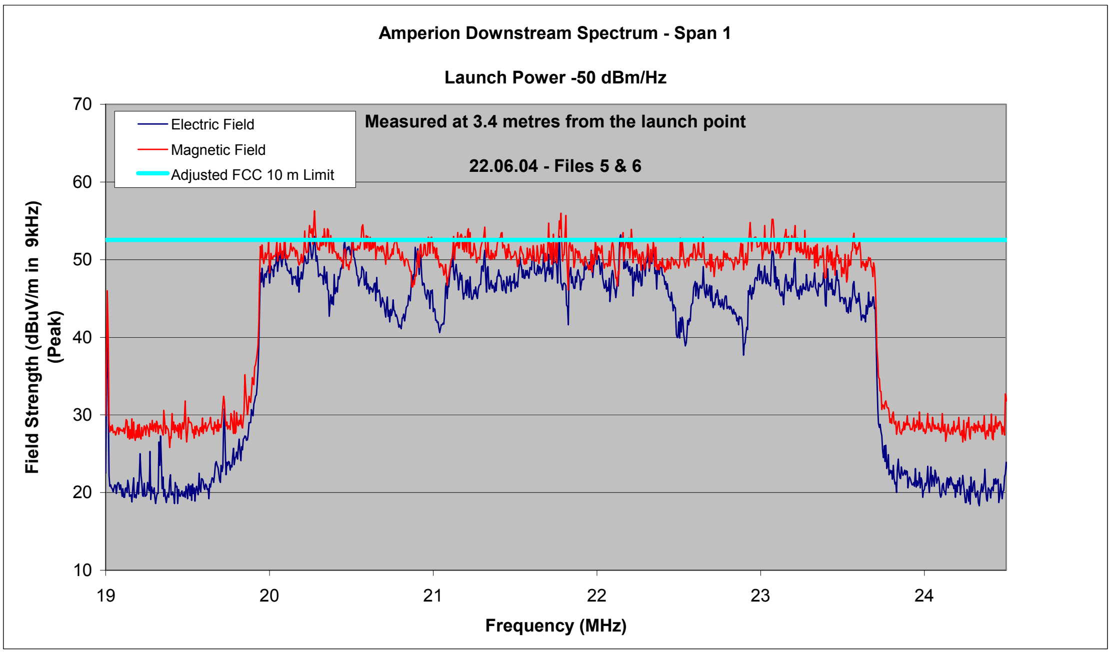


Figure 7 Emissions at 1/2 λ from the injection point – 10 metre measurement

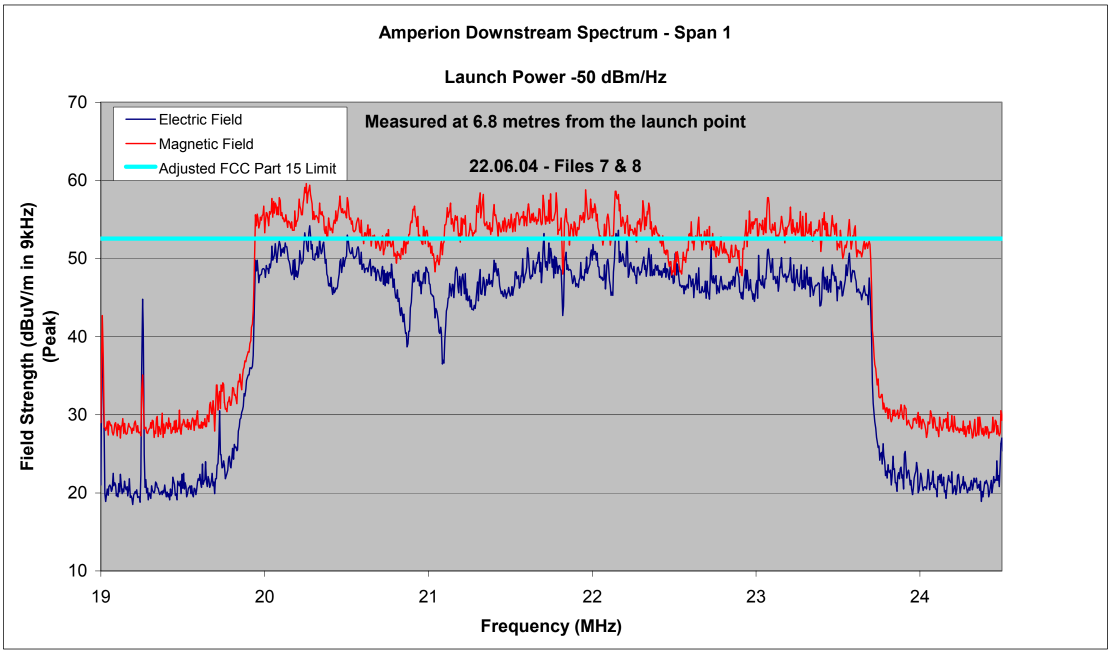


Figure 8 Emissions at 3/4 λ from the injection point – 10 metre measurement

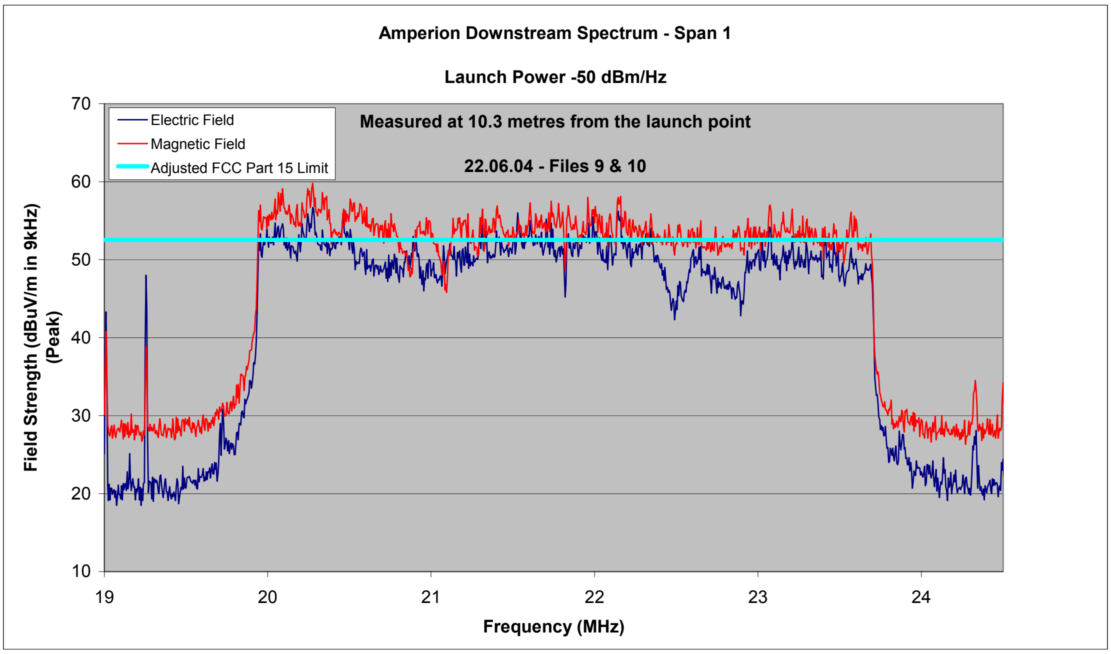
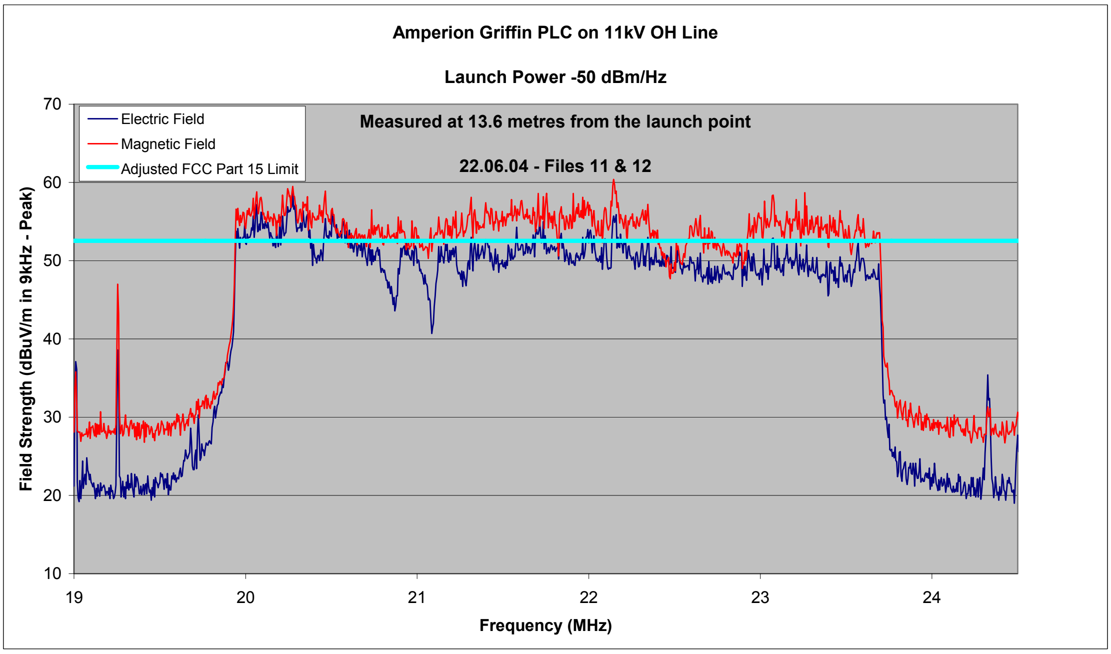


Figure 9 Emissions at 1 λ from the injection point – 10 metre measurement



Magnetic field measurements were made with a Rohde & Schwarz HFH2-Z2 60cm broadband active loop antenna. The measuring system noise floor was 28dBuV/m

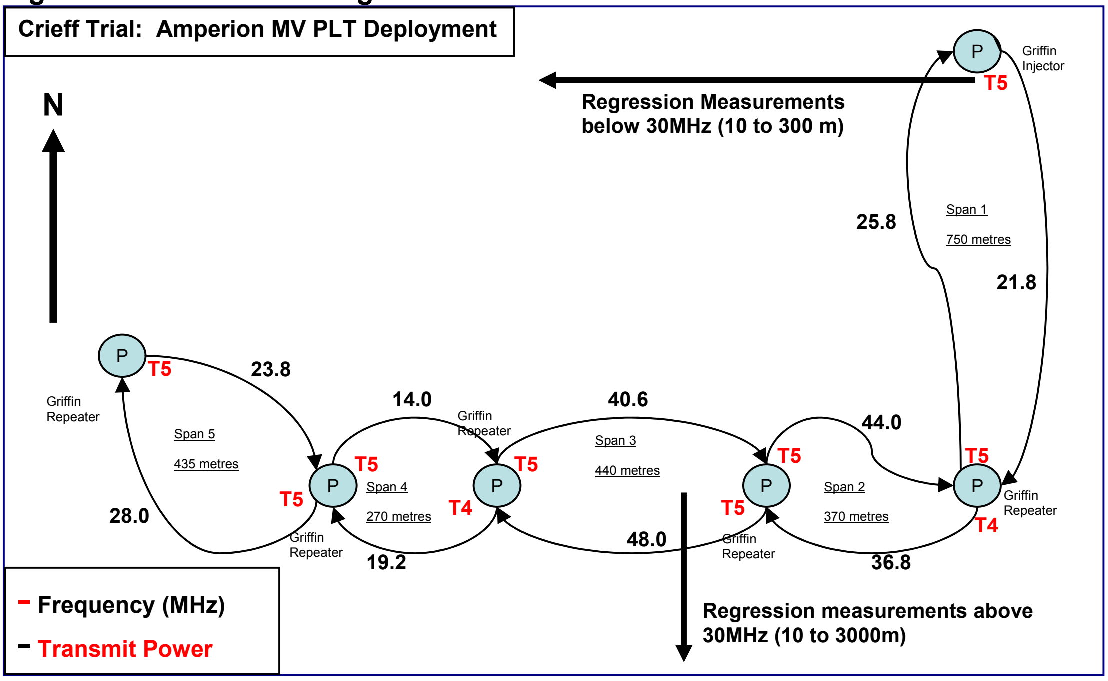
Electric field measurements were made with a vertically polarised Schwarzbeck EFS9219 broadband short active dipole antenna. The measuring system noise floor was 20dBuV/m

Field Strength Regression - below 30 MHz (Span 1)

Regression is the rate at which radiated emissions reduce in field strength as the distance from the source to the measuring point increases. This parameter is most usefully defined in terms of dB field strength reduction per decade of distance away from the source. (20 log d1/d2) Once established it can be used to convert measurements made at one distance to those that would have been obtained at other distances. Similarly emission limits quoted at specific distances from the source can be adjusted for other, perhaps more convenient, measuring distances.

Measurements of PLT signal regression from the 11 kV overhead lines at Crieff were limited to Spans 1 and 3 where straight roads crossed the spans at right angles making access feasible and distance measurement more straightforward. Span 1 employed frequency spectrum below 30 MHz and allowed regression to be measured with both a magnetic loop antenna and an electric field dipole antenna.

Figure 10 Directions of Regression Measurements



The measurements were made along a road running at right angles from the overhead line forming Span 1. **(See map Fig 1)** The road crossed the line adjacent to the injection point. The frequency spectrum used for Span 1 was centred on 21.8 MHz for downstream signals and 25.8 MHz for upstream signals.

Both Magnetic and Electric field strength was measured at 10, 30, 100 and 300 metres away from the injection point on Span 1.

For the magnetic field regression measurements below 30 MHz a Rohde & Schwarz HM525 active loop antenna was deployed. This antenna has a noise floor between 17 and 20 dB below that of the standard Rohde & Schwarz HFH2-Z2 60cm active loop antenna that is normally used for compliance measurements.

Magnetic Field Regression - below 30 MHz (Span 1)

Figure 11 Loop Antenna 30 metres from the downstream launch point (Span 1)

The white fibreglass enclosure housed a low noise Rohde & Schwarz HM525 active loop antenna.

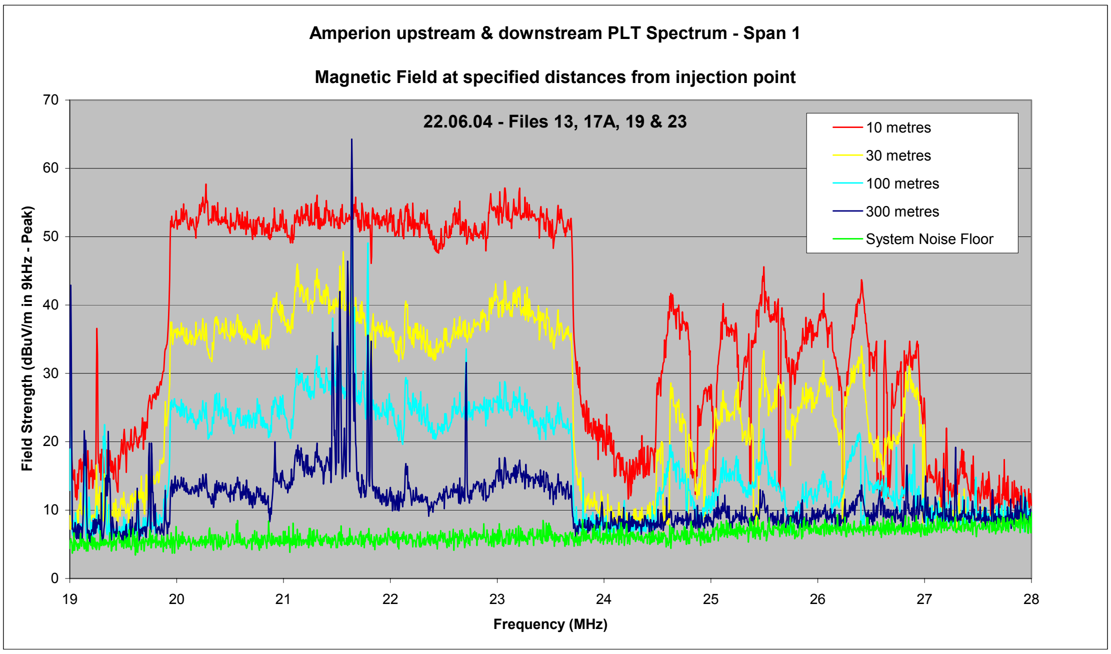
The antenna is shown with the loop parallel to span 1 of the 11 kV line whereas maximum coupling, at this position, occurred with the loop perpendicular to the line.

The Amperion injector unit is attached to the upper part of the pole and the PLT coupler is visible clamped around the central conductor to the right of the insulator bracket.

Span 1 of the 11 kV line overhead runs across farmland, seen to the right of the picture, for 750 metres before reaching the first active Amperion repeater unit.

The chart below shows the magnetic field strength measured at distances of between 10 and 300 metres from the overhead line with the loop antenna oriented for maximum signal at each measuring position.

Figure 12   10 to 300 metre Magnetic Field leakage emission levels (Span 1)



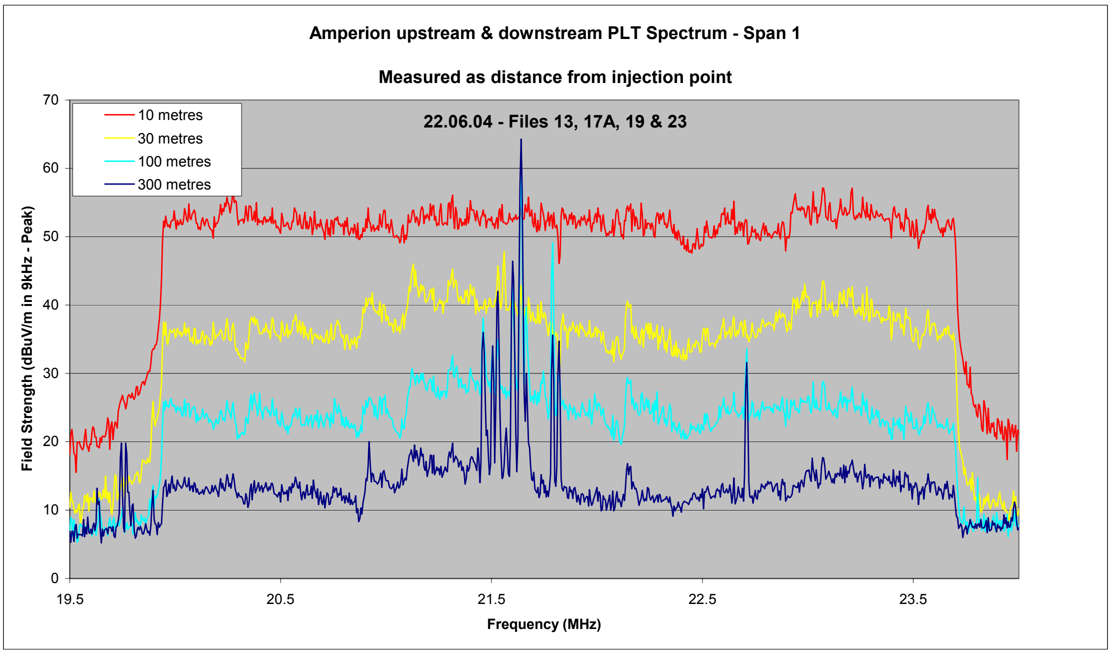
The spectrum block to the left of the chart, centred on 21.8 MHz, is the continuous downstream link from the Amperion injector unit at the launch point on Span 1. The high level narrow band signals seen in the centre of this block are AM broadcasts in the 13 metre band.

The spectrum block to the right of the chart, centred on 25.8 MHz is the discontinuous upstream spectrum from the Amperion repeater unit situated 750 metres from the launch point at the other end of Span1.

It can be seen that the upstream spectrum block appears to show a similar regression characteristic to the downstream spectrum block. This is a good indication that, at the measuring positions, the predominant source of the upstream signal was the section of 11 kV line nearest to the measuring point.

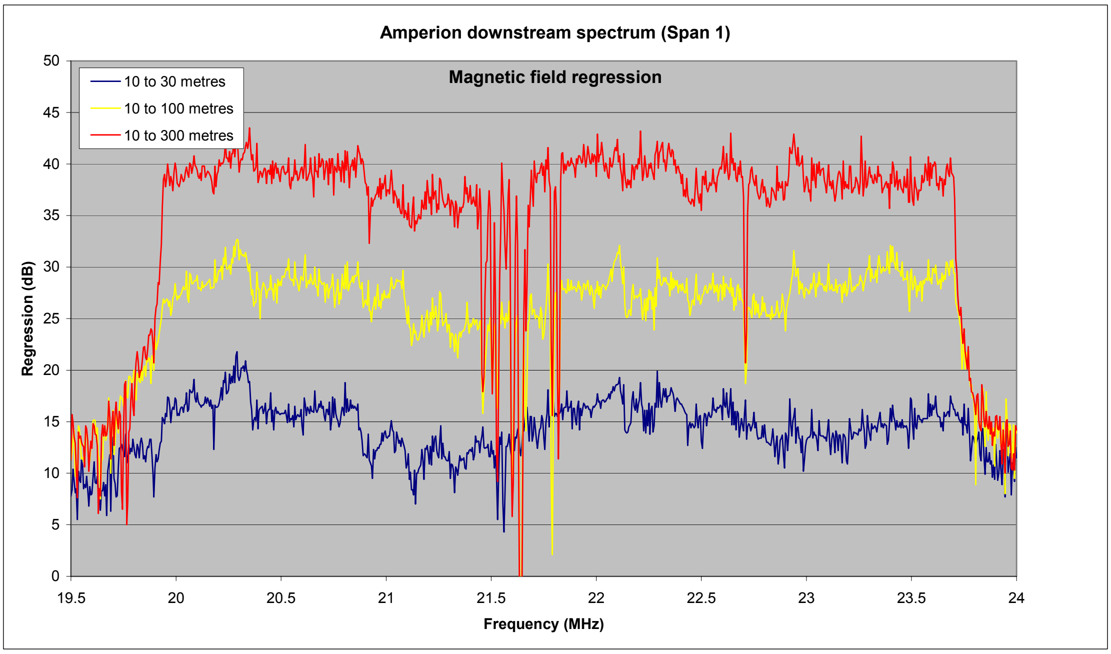
In order to assess the regression characteristic more readily, the chart shown above has been expanded overleaf to show only the continuous downstream spectrum block

Figure 13 Downstream Spectrum Magnetic Field Emission Levels (Span 1)



This chart has been reconfigured below to show the regression characteristic

Figure 14 Magnetic Field Regression Characteristic (Span 1)



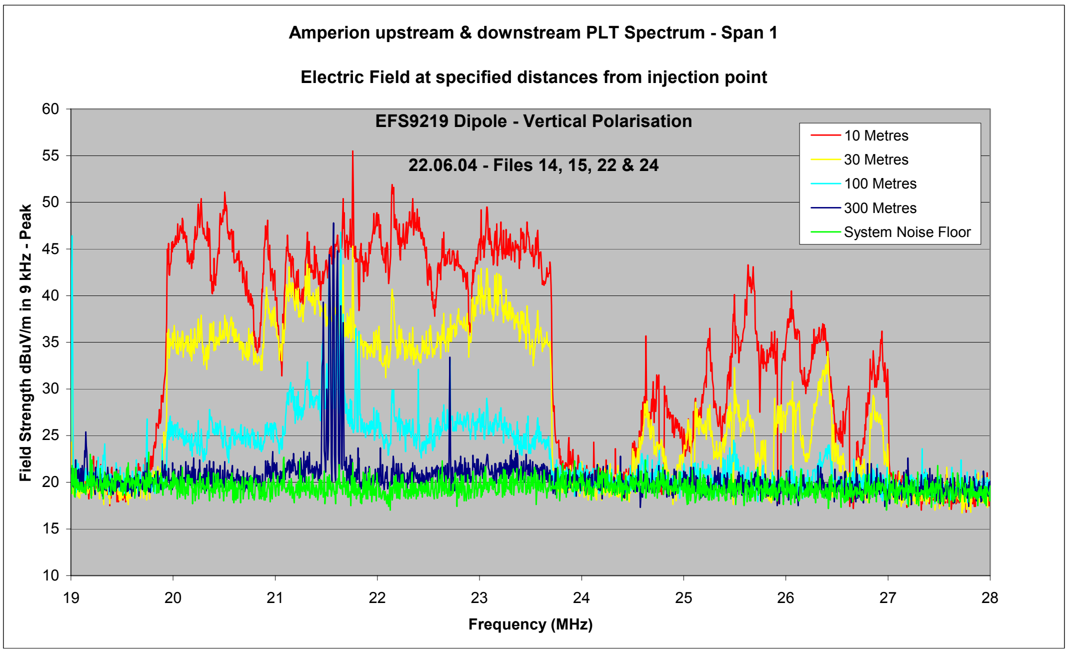
It can be seen that the regression characteristic is quite variable but using the most stable spectrum, around 23.1 MHz, the magnetic field regression values were:

10 to 30 metres	-13.4dB	28dB/decade
10 to 100 metres	-27.9dB	28dB/decade
10 to 300 metres	-37.9dB	27dB/decade

Electric Field Regression - below 30 MHz (Span 1)

Figure 15   Schwarzbeck Dipole Antenna at 30 metres from the launch point

Figure 16   10 to 300 metre Electric Field leakage emission levels (Span 1)



The spectrum block to the left of the chart, centred on 21.8 MHz, is the downstream link from the Amperion injector unit at the launch point on Span 1. The high level narrow band signals seen in the centre of this block are AM broadcasts in the 13 metre band.

The spectrum block to the right of the chart, centred on 25.8 MHz is the Span 1 upstream spectrum from the Amperion repeater unit situated 750 metres from the launch point at the other end of Span1.

Figure 17 Downstream Spectrum Electric Field Emission Levels (Span 1)

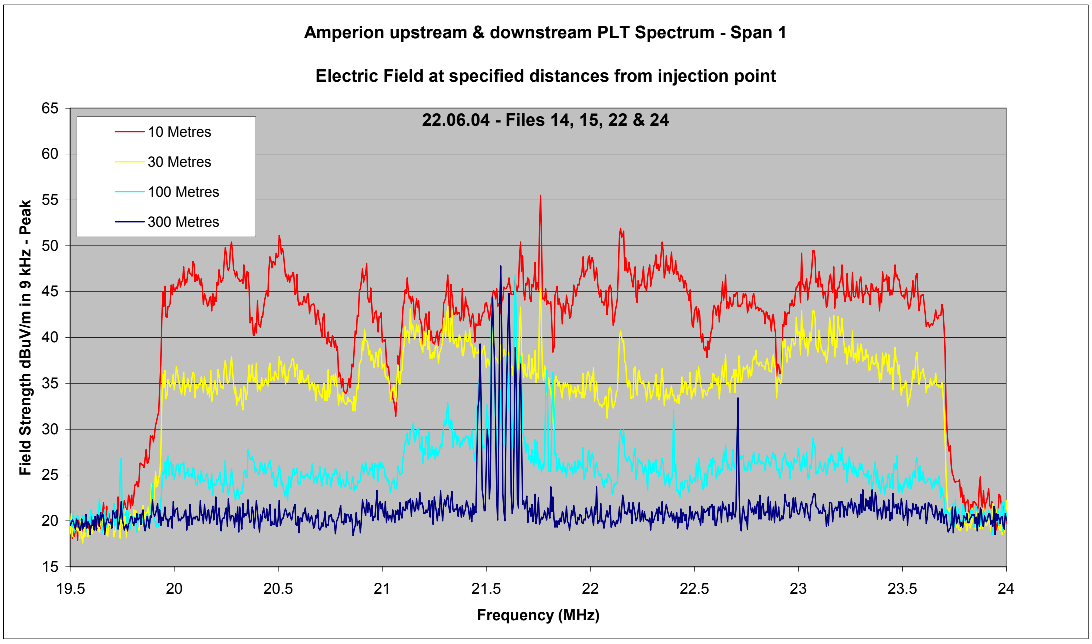
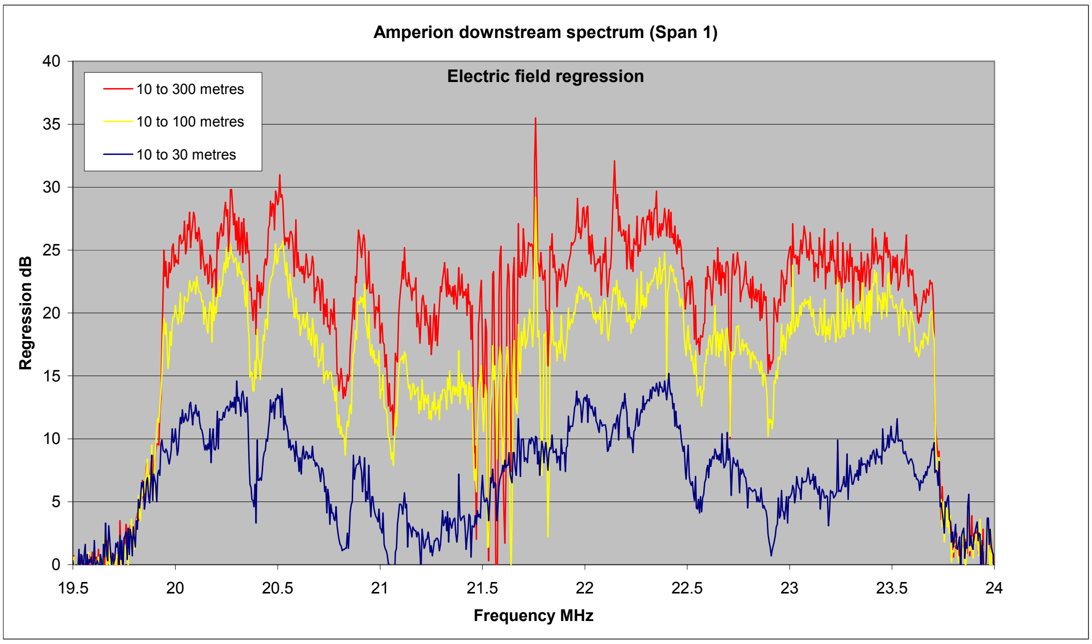


Figure 18 Electric Field Regression Characteristic (Span 1)



It can be seen that the regression characteristic displayed on this chart is highly variable but using the relatively stable spectrum around 23.1 MHz, the electric field regression values were:

10 to 30 metres	-7.7dB	16db/decade
10 to 100 metres	-21dB	21dB/decade
10 to 300 metres	-26dB	17dB/decade

10 metre radiated emission levels for frequencies above 30 MHz (Span 3)

Frequencies above 30 MHz were used on Spans 2 & 3. For measurement purposes only a small section of, the 440 metre long, Span 3 was accessible at a point where it crossed the narrow road shown below.

Figure 19 11kV Overhead Line crossing a road – Span 3

The picture shows the roadside location with a Schaffner Chase VBA6106 bi-conical dipole antenna positioned at the 10 metre measuring point.

This close to the overhead line, torrential rain and high winds dictated that, for safety reasons, the antenna was mounted on a tripod at 1 metre above ground rather than being deployed from a vehicle mounted 10 metre mast.

Both horizontal and vertical polarisation measurements were made in a 120 kHz bandwidth using a peak detector.

Unfortunately the measuring position shown was the only one available and was not immediately adjacent to the launch point so it was not possible to make measurements at ¼ wavelength intervals along the line in this case.

There are currently no radiated emission limits applicable to PLT use within the UK so for reference purposes the American FCC Part 15 limit, applicable to PLT networks in the USA, has been shown in this report.

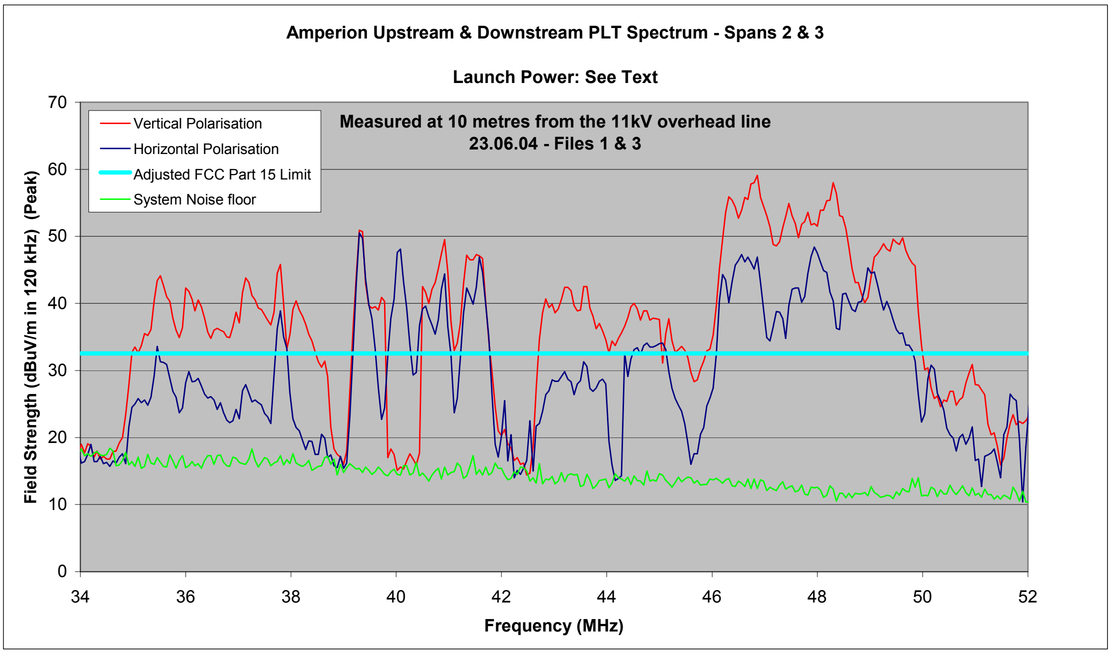
The FCC Part 15.209 radiated emission limit, between 30 and 88MHz is 100uV/m (40dBuV/m) measured at 3 metres from the source in a 120 kHz bandwidth using a QP detector.

To match this to the measuring conditions used at this location, the FCC Part 15.209 limit was adjusted for 10 metres by subtracting the FCC Part 15.31 20 dB/decade distance correction factor of 10.45dB (20 log 3/10) and for the use of a peak detector by adding 3dB to account for the measuring receiver's response to the OFDM signal.

This gave an adjusted FCC Part 15.209 limit of 32.55dBµV/m for this measurement distance and the detector used.

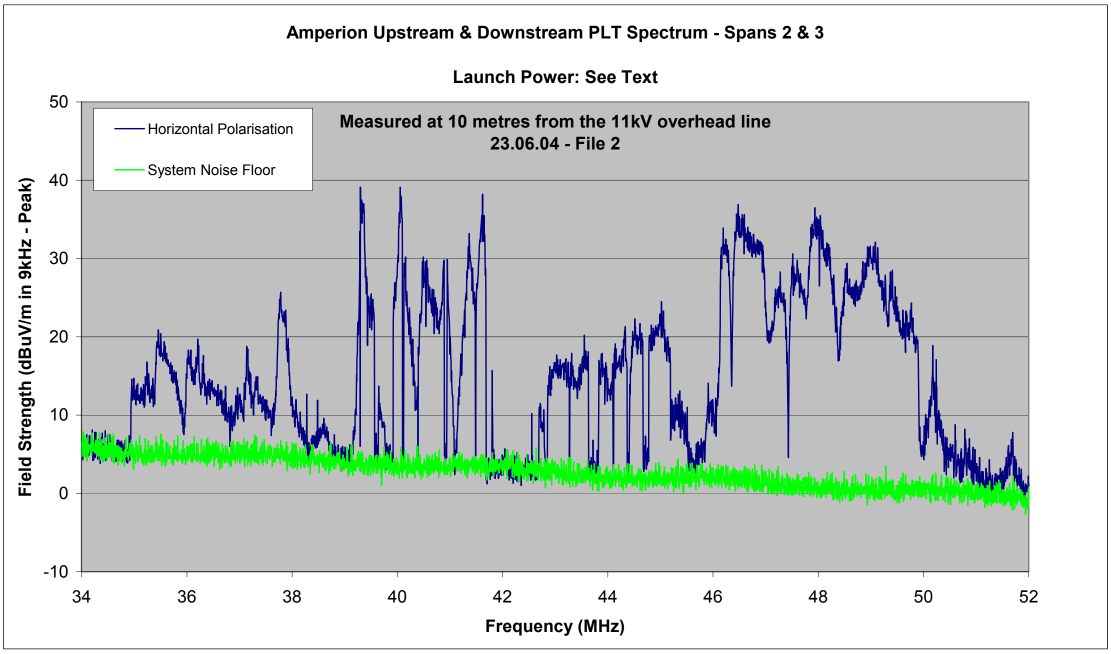
The charts below show upstream and downstream radiated emissions from Spans 2 & 3

Figure 20 10 metre radiated emission levels above 30MHz (120 kHz Bandwidth)



It can be seen that 10 metre emissions peaked at 59dBµV/m, some 27dB above the FCC part 15 limits.

Figure 21 10 metre radiated emission levels above 30MHz (9 kHz Bandwidth)



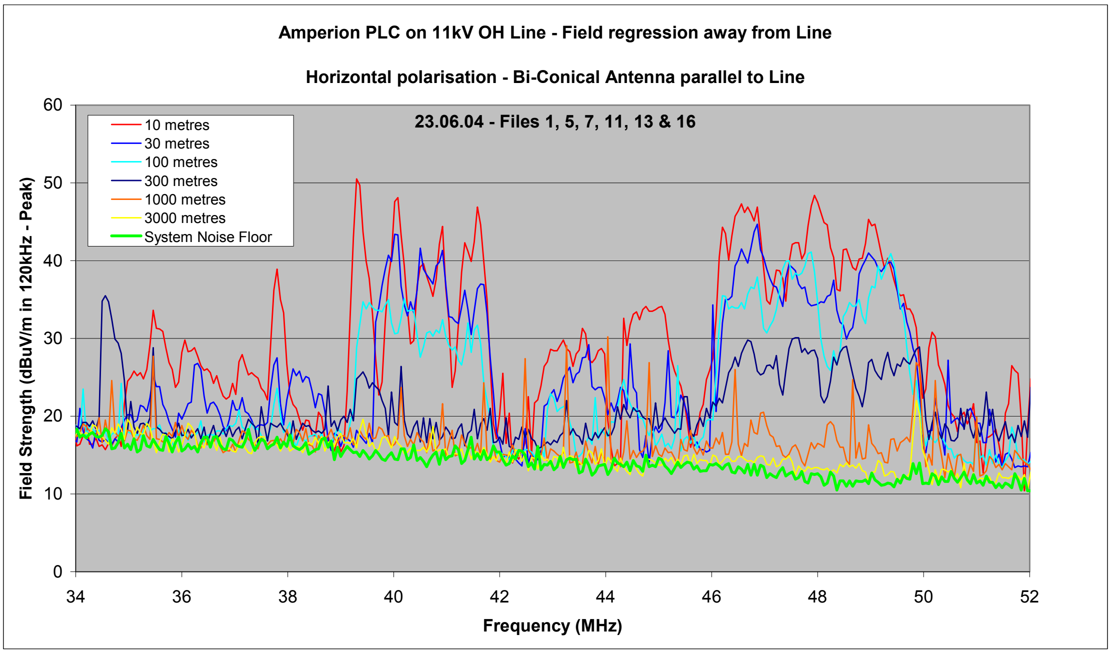
The chart shows that levels measured in 9 kHz bandwidth were approximately 11dB below those measured in 120 kHz bandwidth. (10 log 120/9)

This indicates the noise-like structure of the Amperion PLT signal.

Electric Field Regression above 30 MHz – Away from Span 3

Measurements were made using both vertical and horizontal polarisation but PLT emissions from the predominant 48 MHz spectrum block were only evident at all measurement distances when using horizontal polarisation.

Figure 22 Overall Results for Horizontal Polarisation



The measurements shown in the chart were made along a road running away south at right angles from the overhead line. The 10 metre start point was where the line crossed the road towards the middle of Span 3. **(See fig. 10)**

Span 3 was a 440 metre long PLT deployment that used a 48 MHz downstream spectrum block and a 40.6 MHz upstream spectrum block. The adjacent Span 2, a 370 metre long PLT deployment, had a 36.8 MHz downstream block and a 44 MHz upstream spectrum block.

Table 2

Span	Length	Downstream Spectrum	Upstream Spectrum
3	440m	48.0 MHz ± 1.875 MHz	40.6 MHz ± 1.375 MHz
2	370m	36.8 MHz ± 1.875 MHz	44.0 MHz ± 1.375 MHz

The regression characteristic was significantly more variable than that measured below 30 MHz. This was believed to be due to ground reflections over the measurement path and the effect of making swept frequency measurements with a fixed height antenna rather than single frequency measurements with the antenna height optimised for maximum signal. Using the continuous downstream PLT spectrum, centred on 48MHz, for the analysis, it appears that the regression rate is very approximately 15dB/decade of distance, with values of between 10 and 20 dB/decade, being seen.

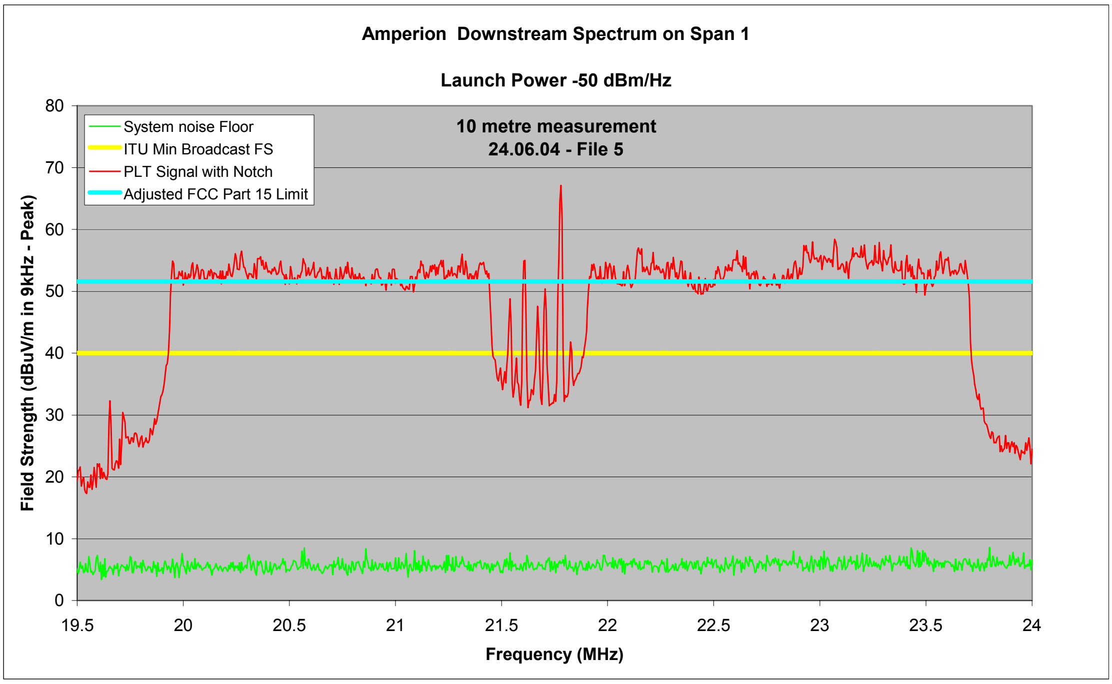
It was just possible to identify the characteristic sound of the PLC signal around 48 MHz at a distance of 3 km from the line and this can be seen on the chart above as a slight increase in the noise floor, on the yellow trace, at that frequency.

Notching

A significant feature of the OFDM chipset used in Amperion PLT equipment is the facility an operator has to adjust the level of individual OFDM carriers within the downstream PLT spectrum blocks. This facility allows a programmed notch to be placed within the downstream spectrum for the purpose of reducing radio interference that may be caused by leakage emissions.

A 20 dB notch, in the 13 metre short wave broadcast band, is shown below.

Figure 23 Span 1 Downstream Spectrum with Notch between 21.45 & 21.9 MHz



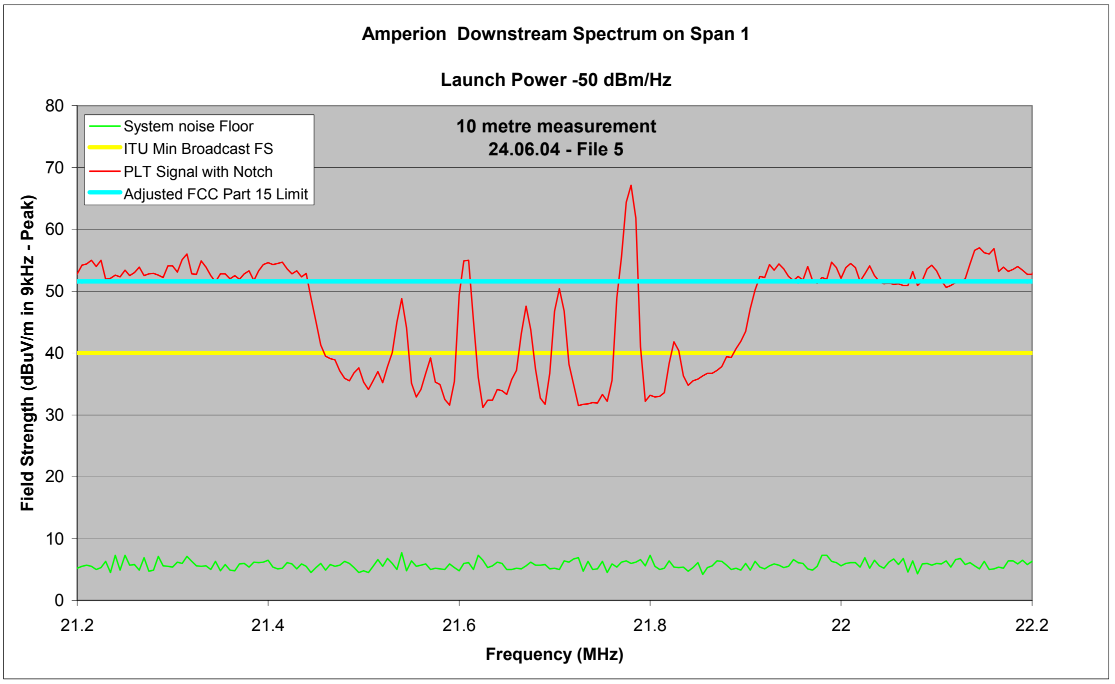
This measurement was made adjacent to the PLT launch point on Span 1, at 10 metre spacing from the overhead line, using the Rohde & Schwarz HM525 low noise loop antenna.

To cover a potentially realistic interference scenario Amperion were asked to implement a 30 dB notch from 21 to 22 MHz to cover both the 21 to 21.45 MHz Amateur Radio band and the 21.45 to 21.9 MHz HF broadcast band. They reported problems with this, due to the bandwidth required, and subsequently the 20 dB notch, shown above, was provided for the 21.45 to 21.9 MHz broadcast band.

Previous experience with DS2 notching ***(Ref. 4)*** *would suggest that a 1 MHz wide 30 dB notch would have been about 3 MHz wide at the 6 dB points leaving very little of the PLT spectrum block available for use.*

It can be seen that several broadcast band signals have been 'uncovered' by the notch and these are examined in more detail overleaf.

Figure 24   Broadcast Signals uncovered by a 20dB Notch



It can be seen that the notch has uncovered a group of AM broadcast stations in the 13 metre broadcast band, most having field strengths in excess of the ITU-R Rec.BS.703 minimum 'protected' value of 40dBuV/m.

Although these broadcasts were not specifically identified, the World Radio & TV Handbook **(Ref. 5)** has indicated that the stations shown in the table below were the most likely occupants of these frequencies.

Table 3   Table of Broadcast Stations uncovered by a 20dB Amperion Notch

Freq MHz	Most Likely Station	Location of Station	Field Strength in 9 kHz peak dBµV/m	S/N within notch (dB)
21.540	Voice of America	USA	49	13
21.610	Radio Exterior de Espana	E	55	23
21.670	YLE Radio Finland	FIN	48	16
21.705	Radio Slovakia	SVK	50	19
21.780	Deutsche Welle	D	67	35
21.830	BBC World Service	CYP	42	7

It is interesting to note that the noise level at the bottom of this notch is close to the noise floor of a typical CISPR measuring system using the standard 60cm active loop antenna such as a Rohde & Schwarz HFH2-Z2.

Had such an antenna been used for this measurement, it may have led to the misleading impression that part of the Amperion spectrum had been ‘notched out’ completely, whereas this is clearly not the case.

Section 6

Observations and conclusions

Leakage emission levels

On frequencies below 30MHz, the maximum leakage emission levels measured were 60dBµV/m at 10 metre spacing from the 11kV overhead line with the full launch power of -50dBm/Hz. These levels are approximately 20dB higher than recently measured by Ofcom from access PLT networks at the same separation distance and using the same launch power but with underground three phase distributors. (Ref 4 & 6)

On frequencies above 30MHz, the maximum leakage emission levels measured were 59dBµV/m at 10 metre spacing from the 11kV overhead line with the full launch power of -50dBm/Hz. These measurements represent the first time PLT frequencies above 30MHz have been encountered by Ofcom/RA so no comparisons with any previous measurements can be made.

Compliance with FCC Part 15 Limits

In the USA, the need for PLT networks to comply with FCC Part 15 limits is confirmed in FCC document 04-245. **(Ref 2)** Paragraph 33 of this document cites the rules contained in FCC 15.109(e) for carrier current systems used as unintentional radiators. These rules require compliance with the radiated emission limits contained in FCC 15.209. It should be noted that there is also a requirement contained in FCC 04-245 (Appendix C) for compliance testing to be carried out at the maximum power setting of the PLT device under test.

For the measurements contained in this report it was not possible to carry out a full compliance analysis, per FCC requirements, as much of the Amperion equipment was installed on 11kV line crossing farmland and thus not readily accessible with the normal road vehicles and laboratory grade test equipment available to Ofcom. It is nevertheless believed that the measurements made were sufficient to indicate the general situation.

Frequencies below 30MHz

For frequencies below 30 MHz radiated leakage emissions the Amperion based PLT network operating at its maximum power setting of -50dBm/Hz exceeded the FCC Part 15 limits by up to 8dB. It is concluded that the maximum launch power levels would need to be restricted to approximately -60dBm/Hz to ensure compliance with FCC Part 15.209 limits on this network at the measurement positions used.

Frequencies above 30MHz

For frequencies above 30MHz radiated leakage emissions the Amperion based PLT network operating at its maximum power setting of -50dBm/Hz exceeded the FCC Part 15 limits by up to 27dB. This large discrepancy between the leakage emission levels measured and the FCC Part 15.209 limit, is due to the launch power not being reduced to take account of the more stringent FCC limit above 30MHz. *The FCC Part 15.209 limit is effectively 30dB more stringent above 30MHz.* ***(see Annex A)***

In practise the launch power would need to be reduced by 27dB to ensure compliance with the FCC limit and this raises two issues. The first is that such a reduction is beyond the 24dB power control range of the product and secondly it seems certain that the network would fail to provide any functionality at such a reduced power level.

It is concluded that the Amperion PLT product as tested is not and cannot be, FCC part 15 compliant above 30MHz.

Compliance with RegTP NB30 Limits

RegTP NB30 radiated emission limits are applicable to PLT networks in Germany and have been under discussion for use throughout Europe for several years.

The NB30 limit from 1 to 30MHz is 40 – 8.8*log f (MHz) dBμV/m measured in a 9 kHz bandwidth at 3 metres from the source using a peak detector. For measurements at 3 metres, this limit is between 35 and 45dB more stringent than the FCC part 15.209 limits. Had the Amperion PLT product been tested to NB30 it would have exceeded the limits by approximately 44dB between 20 and 21MHz.

The NB30 limit from 30 to 1000MHz is 27dBμV/m measured in a 120 kHz bandwidth at 3 metres from the source using a peak detector. Increasing the FCC part 15 limits by 3dB to account for the use of a peak detector on the OFDM signal, the NB30 limit is 16dB more stringent and the Amperion PLT product tested would have exceeded the NB30 limit by 43dB at around 48MHz.

It is concluded that, should the NB30 limits be adopted, within Europe, either for the measurement of PLT system compliance or for adjudication in cases of reported interference, such adoption would rule out any European deployment of the tested Amperion Griffin based PLT product.

Comparison of E & H fields at 10 metres from the OH Line

Within technical working groups some discussion has focussed on the most appropriate antenna to use for close-in PLT measurements. The issue being whether, in the near field, an electricity cable carrying high frequency PLT signals is principally a magnetic or an electric field radiator.

Most of the previous PLT measurements undertaken by Ofcom, RA and others have used a magnetic loop antenna for radiated measurements below 30 MHz. The use of a broadband short active dipole antenna, of compact dimensions, has facilitated close-in electric field PLT measurements. **(Ref. 4)**

The 10 metre measurements of both electric and magnetic field, shown above, indicate a magnetic field dominance of between 0 and about 8dB. This indicates that the logarithmic value of field impedance at the measuring point varied from the free space value of 51.52dB (20 log 377Ω) down to about 43.52dB (20 log 150Ω) at ½ λ from the Amperion injector.

Regression

The use of a scanning measuring receiver has allowed the assessment of field strength regression to be based on the results of 14,400 automated spot frequency measurements below 30MHz and 1800 automated spot frequency measurements above 30MHz. The regression values offered are those derived from a simple visual examination of the regression charts to determine the overall trend in areas of the broadband PLT spectrum least affected by abrupt variations due to reflections. It is believed that this technique gives an adequate overview of the regression situation without the need to make many time consuming spot frequency measurements, each involving height optimisation of the antenna.

The magnetic field regression results below 30MHz, at approximately 27dB/decade, are reasonably consistent with the 20 to 25dB/decade values recently measured on a PLT access network based on underground electricity cables. **(Ref 6)**

The electric field results were more variable, especially above 30MHz, where ground reflections have contributed to regression values of between 10 and 21dB/decade being measured. Values below the free-space spreading loss of 20dB/decade indicate additive summation of the direct and reflected signals arriving at the measuring antenna.

Notching

The Amperion griffin PLT product is based on the DS2 chipset and it is believed to have similar notching capabilities. The notching performance of a DS2 access PLT product has recently been examined in some detail and more information can be found in previous document in this series **(Ref 4)** For this report, the examination of Amperion Griffin notching performance was limited to a 20dB notch, placed in the 13 metre shortwave broadcast. The results were consistent with those previously measured on the DS2 access PLT product referred to above.

It is concluded that the usefulness of the notching facility as an interference mitigation measure is compromised because notches cannot be placed in the 'upstream' spectrum and because the FCC part 15 limit levels are too relaxed to permit the notched spectrum to afford any significant protection to weak signal reception.

Compliance Measurement Procedures for Overhead PLT Networks

The comprehensive FCC compliance testing procedures, detailed in FCC 04-25, require measurements to be made at each injector, repeater and extractor forming part of the PLT network. For a PLT network of any size, work of this nature represents a significant and potentially costly exercise. If such a requirement were to be implemented in UK regulations, the cost may prove prohibitive as UK medium voltage overhead power lines tend to be routed across private land rather than along public roads, as is the more common situation in the USA.

A simpler and less intrusive regulatory approach might be to avoid the need for formal compliance testing by limiting the power spectral density of PLT devices to a level that, in most circumstances, was known not to produce radiated emissions above the relevant limit. The results of this work indicate that, for overhead PLT networks operating below 30MHz a maximum PSD of -60dBm/Hz may be a suitable value to give a presumption of compliance with the current FCC Part 15 limits.

The situation above 30MHz is puzzling because, as indicated earlier, it appears that the more stringent FCC Part 15 limit for frequencies above 30MHz would require a maximum PSD of less than -74dBm/Hz to give even a presumption of compliance.

Measuring Equipment

The use of a scanning measuring receiver in this work has given a useful overview of the radiated leakage emission profile from the overhead PLT network at Crieff without the need for a series of, time consuming but less informative, spot frequency measurements. It is recommended that Ofcom utilise this technique for all future PLT measurements whether for research, compliance testing or adjudication in cases of reported interference.

Section 7

Calibrated Measuring Equipment

DESCRIPTION	MANUFACTURER	Model Number	RTCG Plant
EMI Measuring Receiver	Rohde & Schwarz	ESCS30	2840 & 3178
CISPR Active Loop Antenna	Rohde & Schwarz	HFH2-Z2	2115
Low Noise Active Loop Antenna	Rohde & Schwarz	HM525	Ex Contract
Short Active Dipole Antenna (link below)	Schwarzbeck	EFS9219	On loan from BT Exact
Bi-conical Antenna	Schaffner Chase	VBA 6106	2070

http://www.schwarzbeck.de/Datenblatt/efs9219.pdf

Section 8

References

1.) **‘Amendment of Part 15 regarding new requirements and measurement guidelines foe Access Broadband over Power Line Systems’**

Notice of Proposed Rulemaking FCC 04-29 February 2004
http://hraunfoss.fcc.gov/edocs_public/ attachmatch/FCC-04-29A1.pdf

2.) **‘Amendment of Part 15 regarding new requirements and measurement guidelines foe Access Broadband over Power Line Systems’**

Report and Order FCC 04-245 October 2004
http://www.hraunfoss.fcc.gov/edocs_public/ attachmatch/FCC-04-245A1.pdf

3.) **FCC Part 15**
http://www.access.gpo.gov/nara/cfr/waisidx_98/47cfr15_98.html

4.) **DS2 PLT Measurements in Crieff**

Ofcom Report 793 (part 2) December 2004

5.) **World Radio TV Handbook**
http://www.wrth.com

6.) **Ascom PLT Measurements in Winchester**
Ofcom Report 793 (part 1) November 2004

Section 9

Acknowledgements

Ofcom would like to thank the following organisations for their support during the course of this work.

Scottish & Southern Energy plc:

For hosting this work, negotiating access to farm land for measurements and for providing practical assistance during the measurement processes.

Amperion, Inc:

For providing technical information on the operation of their products and for scripting the spectrum notch featured in this report.

Annex A

List of abbreviations

AM	Amplitude Modulation
BPL	Broadband (over) Power Line (USA)
CISPR	International Committee for the study of Radio Interference
DSL	Digital Subscriber Line
FCC	Federal Communications Commission (USA)
ITU	International Telecommunications Union
LV	Low Voltage
LVEDN	Low Voltage Electricity Distribution Network
NPRM	Notice of Proposed Rule Making (FCC – USA)
OFDM	Orthogonal Frequency Division Multiplex
PLC	Power Line Communications
PLT	Power Line Telecommunications
PSD	Power Spectral Density
RA	Radiocommunications Agency (subsumed into OFCOM UK Jan. 2004)
R&S	Rohde & Schwarz (German test & measuring equipment manufacturer)
RegTP	Regulator of Telecommunications & Posts (Germany)
RTCG	Radio Technology & Compatibility Group
S&SE	Scottish & Southern Energy plc (UK Power Utility)

Annex B

Normalised FCC Limits

If the FCC Part 15.209 limits from 1.705 to 30MHz and from 30 to 88MHz are normalised to a 10 metre measurement distance using a 9 kHz bandwidth, the transition at 30MHz can be assessed as shown below.

1.) The limit from 1.705 to 30MHz is 30µV/m is measured at 30 metres in a 9 kHz bandwidth. For a 10 metre measurement a 40dB/decade correction factor is applied. The 10 metre limit then becomes:

20 log 30 + 40 log (30/10) = 48.62dBµV/m **(A)**

2.) The limit from 30 to 88MHz is 100 µV/m, measured at 3 metres in a 120 kHz bandwidth. For a 10 metre measurement a 20dB/decade distance correction factor is applied. For noise-like signals a 10 log bandwidth correction factor can be applied. The 10 metre limit in a **9 kHz** bandwidth then becomes:

20 log 100 – 20 log (10/3) – 10 log (120/9) = 18.29dBµV/m **(B)**

It follows that, for noise-like emissions with a bandwidth of 120kHz or more, the FCC limit above 30 MHz is 30.33dB **(A-B)** more stringent than the limit below 30MHz.